



21st CIRP Conference on Life Cycle Engineering

Using actor networks in decision making during content-packaging development

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*University of Twente, Drienerlolaan 5, Enschede 7522 NB, the Netherlands** Corresponding author. Tel.: +31 53 489 2418; fax: +31 53 489 3631. E-mail address: e.j.oudeluttikhuis@utwente.nl**Abstract**

In order to integrate sustainability in the development of content-packaging combinations, the consequences of decisions for the entire life cycle need to be analyzed in early stages of the development process. To adequately underpin these decisions, several aspects, for example the economic and the environmental impact, need to be assessed. A so-called actor network is developed to support designers in decision making. This publication examines practical use situations of this actor network tool based on information from research partners. Scenarios are written in order to depict requirements for the actor network tool, considering different users and functionalities.

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Selection and peer-review under responsibility of the International Scientific Committee of the 21st CIRP Conference on Life Cycle Engineering in the person of the Conference Chair Prof. Terje K. Lien

Keywords: actor network; life cycle engineering; decision support; sustainability**1. Introduction**

Sustainability is an important subject for organisations in the field of packaging. While the subject seems to become a persistent part of business strategies, the integration of different aspects of sustainability in daily practice lags behind, especially in the early stages of product and packaging development. This is partly due to the ambiguous role of packaging.

From a resource perspective, packaging is often considered as a major contributor to the environmental impact. As its life cycle is often extremely short, the amount of resources needed to produce the packaging and the amount of waste that remains seem out of proportions. However, from a utility perspective, packaging is an indispensable prerequisite for sufficiently providing modern society. Packaging protects and preserves its content and enables transportation and usage. In fulfilling these functions, a package actually decreases the amount of spoilage and damage during the life cycle. The potential environmental impact of the content often is much higher than the environmental impact of the package [1].

Since packaging is inextricably bound up with its content, consideration of the packed product should always be a core subject during the development of packaging. This becomes all the more true when integrating sustainability in these trajectories. More than with conventional aspects like costs, sustainability enforces an engineer to take into account aspects from unknown fields of expertise, leading to new challenges to overcome.

During the early stages of a development phase, information about certain life cycle aspects is often uncertain, missing or even not yet created. Contradictory, it is this information that is necessary for the analysis of various sustainability impacts. Furthermore, this paradoxical situation is enhanced by a lack of transparency, collaboration and mutual understanding throughout the life cycle. For instance, the notion ‘product’ is different for every actor. Product’ for one company might be the content-packaging combination, while another company considers graphical packaging designs as their product.

This apparent trivial difference potentially has major consequences, especially when aspects from different fields of expertise need to be taken into account. This biased view is often not considered. Consequently, sustainability decisions

are based on incomplete and uncertain models of the life cycle that in turn can lead to sub-optimization.

There are many sustainability tools available to face some of these problems and to explicitly address environmental sustainability throughout product and packaging development. Qualitative tools and methods that can be used during the design and development of a product are often guidelines, principles and checklists. These tools are easy to use and understand. However, extensive experience and knowledge is required to interpret the guidelines in the right way and to avoid sub-optimization [2]. Furthermore, guidelines are not applicable in every case. For example, 'reduce the amount of material' might be a useful guideline for some applications, however in case of packaging, reducing the amount of packaging material can lead to spoilage of the content which increases the overall environmental impact. In order to successfully apply such guidelines, they need to be examined in the right context.

At the other end, analytical tools based on standardized life cycle assessment can be used to simulate and quantify the environmental impacts of a product throughout its life cycle. Information about the entire life cycle is needed to calculate the impacts of the processes regarding several (environmental) categories such as ozone layer depletion, greenhouse effect or depletion of raw materials. Such analytical tools heavily rely on a complete set of life cycle information, which is well-nigh inconceivable during the early stages of product development [2]. In applying analytical tools, the user is forced to make numerous assumptions that decreases not only the workability but also the usefulness and certainty of the results.

All in all, the available tools focus on (an aspect of) sustainability as a separate subject instead of an intrinsic part of the product development processes. Consequently, the requisites of these tools do not adhere to the available time, information and resources of these processes. This severely hampers the effective use of such tools. Since (future) environmental impact is largely determined by the decisions made in the early stages of the development process [3], it is worthwhile to bridge this gap.

In order to integrate sustainability in the development of content-packaging combinations, the consequences of decisions for the entire life cycle need to be analyzed in early stages of the development process. More aspects than only the environmental impact should be included in these assessments. Furthermore, a tool that can be employed in the

early stages of the design and development process of content-packaging combinations should adhere to the available time and resources within a development trajectory. The research described in this paper uses the so called actor network approach to accomplish this. With the fundamentals of this approach in place, its practicality for different key users is explored. From the various use scenarios the requirements for future development of the tool are deduced.

2. Actor network approach

With packaging, it is essential to take the content into account when analyzing environmental impacts, as packaging always has to serve the content-packaging combination in fulfilling its core functions. An attuned interaction between the content and the packaging is thus decisive. Consequently, the life cycles of both the content and packaging needs to be incorporated in any (environmental) sustainability analysis on packaging. The life cycle of a content-packaging combination actually consists of two interwoven life cycles. Moreover, every process in the life cycle consist of local cycles that could be important in analyzing the consequences. For example the life cycle of coal that is needed for the production of steel plates for cans. When these sub-processes are included in the entwined global life cycles, a so actor network emerges [4].

In order to integrate an aspect like environmental impact in the development process of content-packaging combinations, this complex life cycle network needs to be analyzed to avoid the before mentioned sub-optimization. Since decisions made in the early stages of the development process potentially have the greatest impact on the life cycle without having too much consequences on direct costs, the approach developed in this research aims at fostering these early phases. With the actor network approach, comprehensive subjects like sustainability can be addressed by merging a life cycle engineering perspective with the daily working environment. The approach enables the simulation of the entire life cycle as a network of actors that reflects the common activities between businesses. Based on readily available information and information based on earlier experiences, the network structure can be build up and filled with relevant aspects.

Dynamically structuring the information allows for depicting the status quo as well as future scenarios. As such, the approach allows for concurrent decision support during the design and development of product-packaging combinations. It is complementary to existing (environmental) sustainability tools, for instance the network can be used as a framework in which the consequences of guidelines can be examined, furthermore the network can also help in making an inventory for a life cycle analysis.

Based on conceptual graph theory, the network modeling approach not only has a well-developed mathematical foundation which can be used to analyze a system, it can also be used as a means of communication because of its logical graphical representation [5]. Figure 1 shows a representation of the basic building block for the information structure. A life cycle can be modeled by linking so-called actors and adding information to both the actors and their relations.

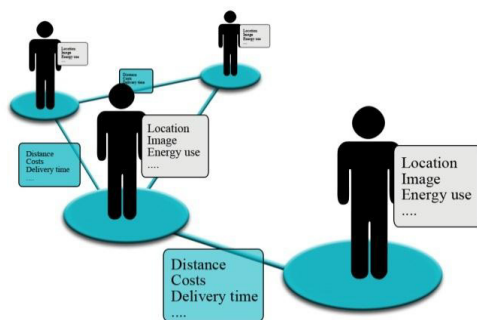


Figure 1: actors, relations and aspects

Actors are considered to be individuals, departments or organisations that are connected with aspects like location, image or energy use. The combination of information about the aspects that is included gives a characterization of the actors. In a similar manner the relations between actors are defined. However, whereas aspects of an actor are solely dependent on that actor, the aspects of a relation are always dependent on both the connected actors. For example transport distance, costs or delivery time are relational aspects which are always influenced by two parties.

As described in section 1, there are multiple views on the definition of the products and their development throughout the life cycle. Because the actor network approach is aimed at modelling the complete life cycle, these different views need to be taken into account. To avoid misinterpretation and sub-optimization the origin and context of the information should always be available. Furthermore, in recognizing these various viewpoints, the underlying network structure should not prescribe any hierarchy. Maximum flexibility is needed for the information structure in which no hierarchy can dominate another. Consequently, the aspects that are used to make a characterization, should not be subordinate to its actor or relation. Within the information structure, an actor and aspects are thus equivalent elements. The resulting flexibility that is allowed in structuring the information is a key element in merging various viewpoints and enabling the integration of global aspects of the life cycle in the specific actor situation.

As the network is intrinsically flexible and infinite in theory, this allows for efficiently re-using the stored information. Frequently occurring structures can help in modeling life cycles during the development process when actors are not known or certain. For instance, a previously drawn-up life cycle around pet-bottle production can be used as a template for future comparable situations.

As the network structure is used to prevent bias, it is important to realize that the network is always approached with a certain view. In enabling the use of the flexible structure, so-called autorarchical structures are deployed [6]. These structures are temporal hierarchies that depict a certain viewpoint and enable meaningful access to the information for its user. This temporary model can be employed in analyzing consequences of decisions. A first example of a tool based on the actor network approach is shown in figure 2. As this first prototype of the tool is aimed at proofing the principles described above, it shows the core functionalities in the most basic form. At the left the actor network (depicting

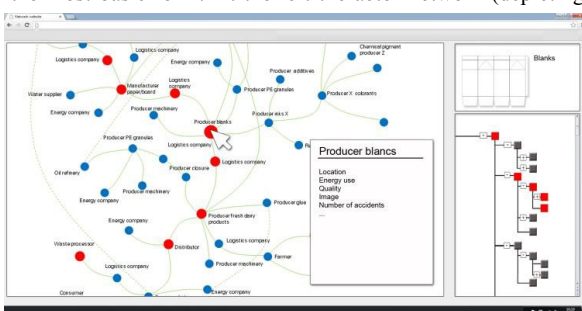


Figure 2: First visualization of an actor network tool
(not intended to be readable)

the life cycle) is shown. In this example, the actors involved in a life cycle of milk in a milk carton are depicted. At the right, a conventional product tree structure (stemming from e.g. a cad-model) is shown. This example shows a bill of materials of a packaging system for milk. The information structure (backend) allows the interconnection between both parts and with the aspects of the actors and relations, the consequences of a change in the design can be mapped on the actor network. Various elements can be changed, added or removed and the consequences of these adjustment can be assessed.

Whether the approach will succeed in its aim to foster the integration of sustainability in daily practice, will largely be dependent on the 'fit' of the corresponding tool within the working environment of its different users. The diversity in this user group has important consequences for the further development of the approach and corresponding tool as probably not one user interface or solution will live up to everyone's expectations. It is thus essential to explore the various use scenarios in advance to extract important requirements for future development of the tool.

3. Use scenarios

To examine the diversity of the user groups, three extreme use scenarios are depicted that cover three important stakeholders always present in a content-packaging life cycle: the producer of the packaging material, the (food) company filling the packaging and the retail business that sells the content-packaging combinations. The scenarios are based on information from research partners in the field of packaging.

3.1 Small brand owners

The market of fast moving consumer goods is flooded with small 'green' brands. The corresponding brand owners use a specific subset like fair trade, biological agriculture or corporate social responsibility as main proposition. Consequently, sustainability is of paramount importance for such relative small brand owners. Their main business activity is focused on the brand and the corresponding product portfolio. Actual development, production and packing is done via partners or co-packers. The organization thus has a guiding role rather than an executive role. The type of packaging is largely determined by these external stakeholders, as internal development is mainly focused on the graphical design. However, the final decision on a packaging concept still is made by the brand owner. With this one decision, the larger part of the future environmental impact is set. In recognizing this influence, the organisation has set up a set of guidelines that steers sustainable packaging development and provides the necessary counterbalance for the dominant factor of costs. The actor network tool is employed in applying these guidelines and analysing the consequences.

The organisation is largely dependent on external parties for the necessary information. Working from a basic office software environment, the regular documents containing e.g. generic packaging specifications, graphic designs, price

arrangements and product compositions form the basic internal input for setting up the life cycle. In complementing the resulting life cycle with available template-information, the appropriateness is determined. So-called white-spots can lead to a request for more specific information about certain aspects. In this way the actor network can aid in assessing basic guidelines on for instance responsible sourcing. With a life cycle in place and stored in the actor network, more elaborated guidelines on packaging development can be examined via scenarios. The consequences when applying a reduction in material or a complete new alternative concept can be compared with the status quo. Furthermore, subjects like the suitability of current partners or selection of new suppliers can be assessed. Moreover, an analysis of the overall life cycle becomes more readily available, without the need for specialist software or hardware. As the information structure grows with every case done, doing the routine becomes more efficient and the organisation can learn from previous work.

3.2 Food processing companies

For larger organisations the actor network can fulfil equivalent functionalities as the ones described above. The differential circumstances for e.g. a large food processing company is that research & development as well as the larger part of production is mostly done indoors. Consequently, different demands and additional functionalities are required which are illustrated here. Focusing on the content-packaging development, which has a strong connection with marketing, projects have a relative short time-frame of about a year. In the project team, different departments are involved in various stages of the development trajectory: marketing, packaging development, product development, purchase and production. When expert knowledge is needed on for instance a new material, new machine or life cycle analysis, external parties are involved.

Sustainable development is included in a strategy containing goals set for 2020, important subjects in these goals are climate change, energy consumption, water footprint and waste prevention. Several of these key issues are measured and monitored throughout the organisation. Daily practice however learns that the goals do not resonate on the work floor. As aspects like costs and quality have a more direct impact on revenues, these are unwittingly prevailed at the decisive 'gate' of each stage. Simplified LCA-tools have been used, but are still bound to a few employees with some background in life cycle engineering.

The actor network tool can furnish the appropriate support at these gates, provided that it interfaces with essential software already in use. Information residing in programs such as for example project management software and resource planning software, can deliver input for the actor network. Besides, information on both the overall sustainable goals and the specific functional requirement specification help in setting the right decision criteria. In combining both types of resources, the resulting actor network reflects the company's current situation without the need for extensive analysis or administration. Furthermore, it can depict not only

the external parties involved in the life cycle, but internal actors as well. As the network is able to capture different views, it not only helps in illustrating responsibilities and interfering differences between departments, it also allows meaningful access to the information tailored to its diverse users. For instance when trying to reduce the weight of a PET-bottle, the limitations set by the existing filling machinery are apparent for a packaging technologist. A more contextual representation might be needed to explain this to representatives from overhead departments. The views and filtering options of the actor network aid in accomplishing this more effectively. Furthermore, it also helps in considering aspects on costs, quality and environmental issues in a more comparative assessment. As specific situations can be compared with general frequently occurring structures, information gaps can be located. For instance, a lack of environmental data on a new packaging material might lead to requesting more specific information from the external LCA-expert. In the meanwhile, rough estimations, derived from previously done cases and general templates prevent the project from stalling.

3.3 Semi-manufactured packaging producers

Moving to the material and semi-manufactured packaging suppliers, development trajectories gradually grow in time. As an example, the development of a new (packaging) material takes approximately 8 years and needs many specialized engineers. The needed investments on production lines are substantial while the future use scenarios of the material and corresponding packaging concepts are only vaguely known at most.

Driven by strict governmental legislation, environmental impacts of the production facilities are closely monitored. LCA studies are done on a regular basis to check whether the set goals on carbon footprint and energy usage are reached. As the focus has gradually shifted towards sustainable development, these environmental issues also need to be addressed on beforehand, during the development trajectories.

In deciding upon the specifics of the new material, it is crucial to meet the requirements set by the (future) customers, current legislation and production methods, as these decisions have major consequences on investments and therefore the future of the company.

Supporting these complex decision processes, the actor network tool can help attuning and levelling the diverse areas of attention. In-house experts on e.g. costs, quality and life cycle analysis can examine the specific consequences of development decisions and can integrate relevant themes and frequently used algorithms in the actor network. With this information, engineers can use the actor network tool to estimate the needed alterations for the new material. Furthermore, using generic template information as well as input from user situations more profound insight in the (future) use phase can aid the development process.

The same holds true for incorporating the recycling process: using the actor network tool as part of the digital working environment enables the integration of end of life scenarios with the current development.

3.4 Input for further development

As can be concluded from the use scenarios described in this section, many different users can employ the actor network tool. The users have different tasks in employing the actor network. The differences between the organisations and the corresponding development trajectories requires for a flexible tool with the possibility to include different views on the life cycles and important aspects. The next section describes more specific requirements regarding the actor network tool.

4. Requirement specification

The described user functionalities from the scenarios can be allocated to various requirements. This translation is aimed at timely incorporating the various users within the further development of the actor network tool. Overall, the actor network needs input on the involved actors, information about aspects of the involved actors in the life cycle and information about their products that is required for the analysis, based on essential decision criteria from the organization or goal under consideration. For analyzing the input regarding these decision criteria, mechanisms are needed. These mechanisms can be employed in analyzing several life cycles and are characteristic for an organization. Another functionality is generating output. This user has to compare different scenarios in order to analyze the consequences of decisions. Control over the system is required for the authorization of users and for a clear overview of current and past projects.

4.1 Input necessities

It is essential that the tool is suitable for different users with different views, backgrounds and working environments. Consequently, a viewpoint and case are always required as starting point to use the actor network tool.

A first step in deploying the actor network is modelling the current life cycles of the content-packaging combinations. As seen in the scenarios, the resources for this input can vary significantly, ranging from direct user input to interfacing with existing information repositories already in use. It should be able to use these resources as input for the actor network. More importantly, this should be done within the available time frame which is dependent on the corresponding development process.

When from a specific viewpoint and case, the complete life cycle network is unknown and the corresponding information structure contains hardly any information about involved actors and related life cycles, it should be able to use generic information to model a life cycle. As this generic information can be generated by making assumptions based on for example material specifications, annual reports of actors or material analyses of existing packaging, the tool should aid in not only processing this information, but should also be able to capture the assumptions that lead to the information.

In case of a comprehensive and well-developed information structure, information about the actors involved

in the life cycle are already included in the database. In this case, the tool should help in selecting the life cycle, the actors and their relevant aspects adequately from the database. Such adequate selection is important to avoid a very complex and time consuming analysis, however when the selection is too small, consequences can be overlooked. The actor network tool should help in the selection of actors and information by taking into account relevant context.

Moreover, this selection should be reversible, thus if a user has second thoughts about a certain actor or aspect, the previously chosen selection should be altered without losing information or too much time.

4.2 Efficiently (re)using information

When the database of the overall actor network gradually grows, the tool can aid the user by reusing the information. It should be possible to employ earlier experiences (from other life cycles). Frequently occurring structures in the database should be available as template to construct the life cycle. In using these structures, it should also be possible to hint at important lacking information. When not all necessary information about certain crucial aspects are known, the user can take action accordingly, e.g. contact the corresponding actor to obtain the necessary information.

Another way of reusing the information that already resides in the information structure, is when the initial life cycle is somewhat vague, uncertain or not known yet. Often recurring structures in the database can be employed to model the life cycle. These templates can be supplemented with information which can be found by analyzing materials (starting with material specifications) and actors that are required in the provision of these materials. When more specific information is known, the tool should be able to complement or replace the previously used generic information. In all these situations, the reliability of the data should always be incorporated when using the information for analyzing consequences. For modelling the life cycle, the actor network should provide for efficient (re)use of the already available information within the available time.

4.3 Mechanisms

The input of the actor network stems from diverse sources. In using the mathematical foundation of the conceptual graphs to its full extend, it should be possible to use both qualitative and quantitative information in a calculation or assessment. Furthermore, expert systems or (human) resources should be able to link their methods with the actor network tool or use the information from the actor network as input. The actor network tool can be employed in order to facilitate this integration. Existing tools for sustainability, costs or quality can be employed. It should be possible to integrate these within the actor network tool to make more in-depth assessments regarding these aspects possible. It should be possible for the expert to update the mechanisms in order to stay up to date and to distribute the mechanisms to other actors if desired. The input that is needed to calculate the impact regarding the decision criteria has to be determined by

the expert and included in the actor network by adding necessary elements to all relevant actors and highlighting the information that is required for the assessments. The mechanisms that are developed to generate the desired output from the input, can be used for analyzing every content-packaging combination and is not specific for a certain life cycle. If any external mechanism are used in an analysis, its origin, approach, limitations and scope have to be transparent in order to enable efficient use.

4.4 Analyzing consequences

Once the actor network is mapped and corresponding information about the actors and the products is included, it has to be possible to make adjustments to this main life cycle in order to analyze the consequences of that adjustment. The actor network should enable such comparison between multiple situations. Several adjustment can be made to the basic scenario. A group of actors can be changed or added for example in case of adding another material to the content-packaging combination. It should also be possible to analyze the consequences of a little adjustment, for example by decreasing the amount of material a little. Furthermore, it should be possible to analyze the consequences of choosing other suppliers or customers.

In determining the elements that are affected by a change in the scenario, the actor network should take a larger selection into account to avoid unnoticed consequences. The result of adjusting elements in the actor network tool, can be highlighted elements that indicates the elements that are influenced by the adjustment. It should be possible to analyze consequences by selecting the element and analyzing the highlighted information that is added to the element. The user of the actor network tool has to interpret the results and can make a decision based on important decision criteria taking considered consequences regarding the life cycle into account. Assumptions have to be taken into account in the results. The probability of the results is essential in giving not only a result but also a bandwidth of its reliability. When more specific information is available, this information can be included in the life cycle and the bandwidth of the results decreases.

As the user group shows great variance, the visualization of the actor network, the various scenarios and any results cannot always be determined on beforehand. Therefore, it should be possible to adjust the interface and allow multiple visualizations of the same information. Overall, the actor network in this manner should provide for meaningful access that is tailored to its users.

5. Concluding remarks

The actor network approach is aimed at practical usability in different development trajectories for users with different views and working for various organisations. As the fundamentals of the actor network are in place, the user requirements described in this paper can serve as input to detail the tool. Different functionalities are derived from the use scenarios: input needs to be generated, consisting of a life cycle including actors, relations and information about both,

mechanisms are required in order to analyze aspects or decision criteria and analysis is needed to make decisions regarding the content-packaging development. The tool has to deal with uncertainties and missing information to allow for a tool that can be employed during the design and development of content-packaging combinations. During the development phase an uncertain or yet unknown life cycle needs to be depicted. Templates and using generic information can help users in depicting life cycles. These possibilities provides for a tool that can be employed in the time and resource-frame of development trajectories of content-packaging combinations. The actor network tool can, for example, be a means of gathering information for executing an LCA.

It would be effective that users who interpret and employ the results of the analysis are also authoritative for providing the required inputs, because they have an overview of the corresponding basic life cycle and important decision criteria in the related case. Furthermore, in combining these two roles, unnecessary administrative tasks are avoided. Noise in communication and (re)collecting unnecessary data can be avoided.

As the first prototype of the actor network tool need to be elaborated to meet the found requirements, future steps include development of principle solution for template structures, incorporating and depicting various views and testing with end users. Furthermore, the integration of already existing databases which contain product specifics and information about actors, would be useful in the depiction of actor networks. As the approach is based on effectively (re)using information, a future challenge will be to adhere to the intellectual property of the involved organisations. As it will be pivotal in integrating the actor network approach in the daily practice of such a variety of users and their working environments and providing them insights in their decision making in sight of balanced life cycles.

Acknowledgements

The authors acknowledge the support of the Dutch ministry of Economic Affairs, Agriculture and Innovation.

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